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Greene

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(54) **DEPICTION OF RELATIVE MOTION OF AIR TRAFFIC VIA AN AIR TRAFFIC DISPLAY**

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G05G 5/00 (2006.01)
G08G 5/00 (2006.01)

(52) **U.S. Cl.**
CPC ***G08G 5/0021*** (2013.01)

(58) **Field of Classification Search**
CPC combination set(s) only.
See application file for complete search history.

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U.S. Appl. No. 13/475,666, filed May 18, 2012 entitled Depiction of Relative Motion of Air Traffic Via an Air Traffic Display.

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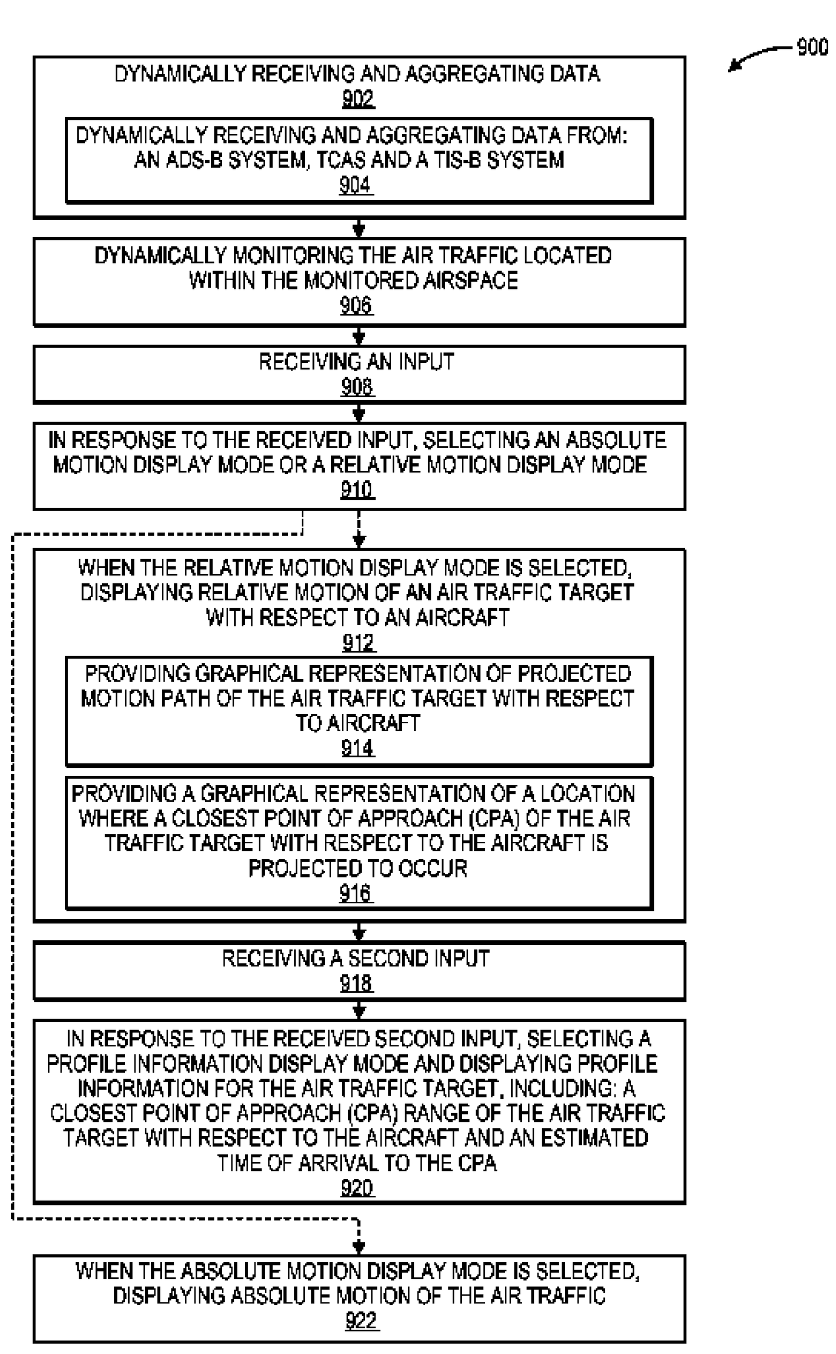
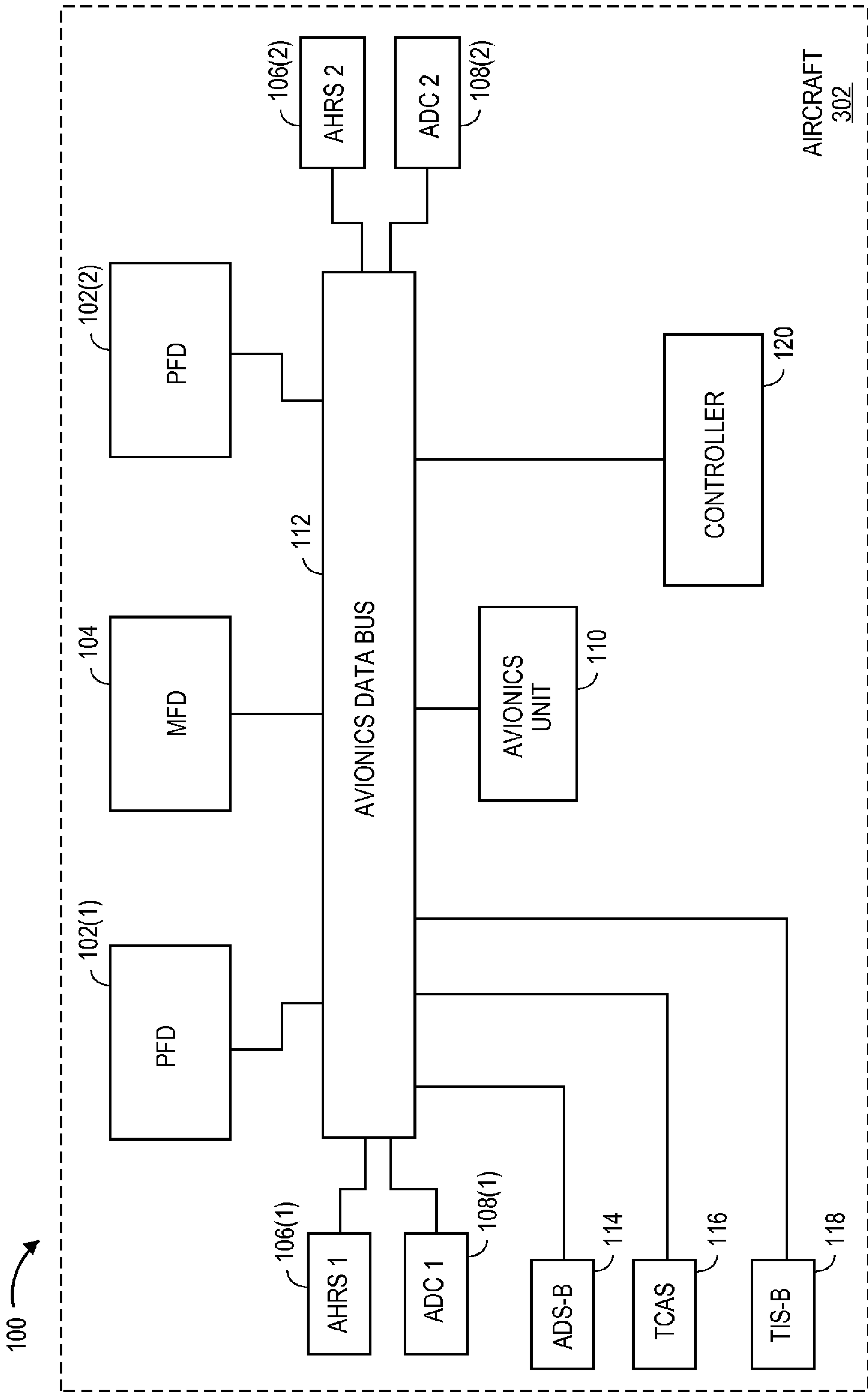
(57) **ABSTRACT**

Techniques are described that allow an air traffic display of an aircraft to display the relative motion of air traffic proximate to the aircraft. The air traffic display may be switched between a first display mode in which absolute motion of air traffic is displayed (e.g., motion of air traffic targets relative to a fixed point on the earth's surface or relative to an apparently fixed celestial point is displayed) and a second display mode in which motion of air traffic targets is displayed relative to the aircraft. The techniques further facilitate the selection of individual traffic targets from a displayed traffic depiction to activate a third display mode in which additional information about the relative motion of the selected target, such as its estimated closest point of approach (CPA) to the aircraft and the estimated time it will take the selected target to reach the CPA are shown.

13 Claims, 9 Drawing Sheets

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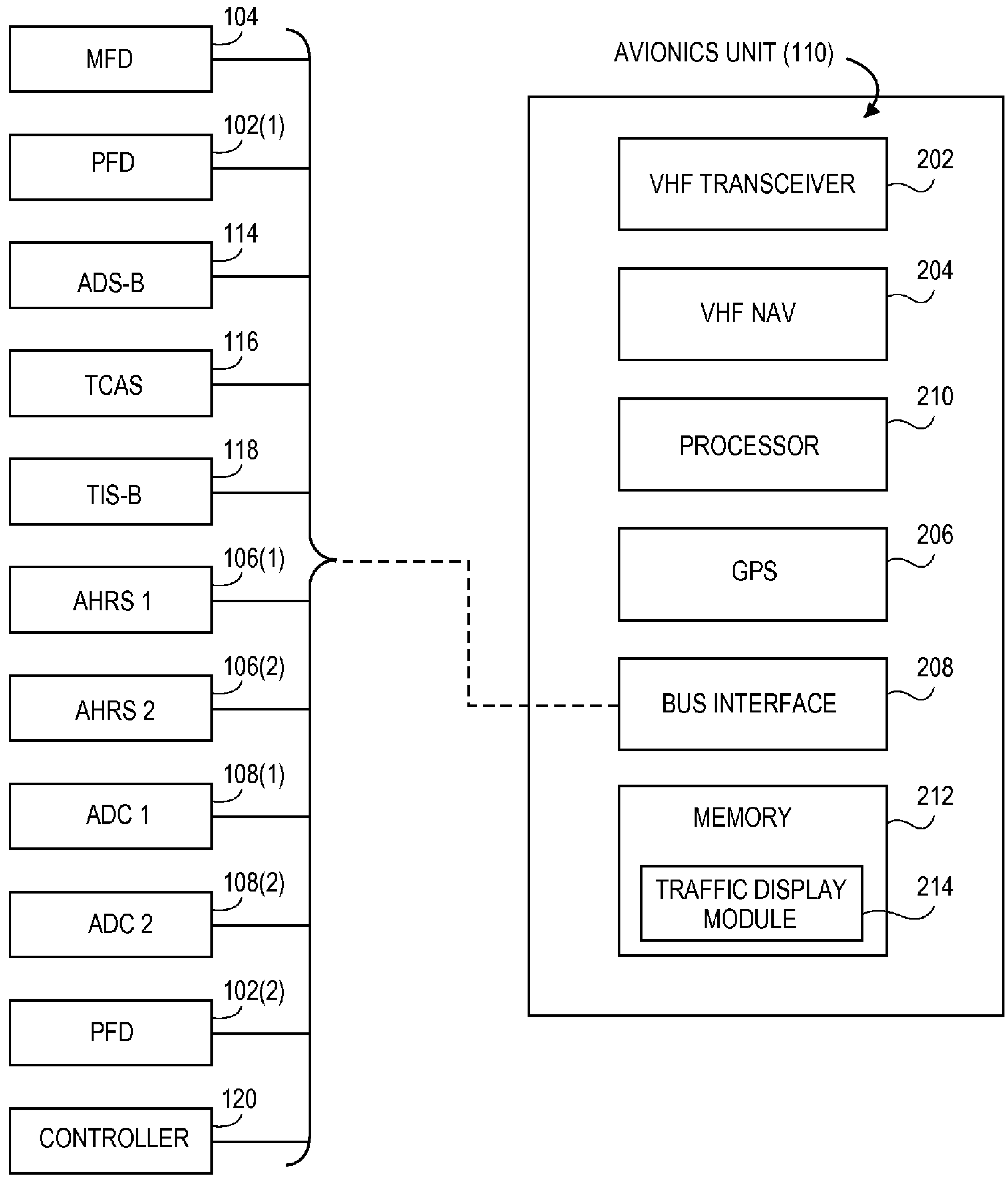
AIRCRAFT
302
PFD
102(2)
MFD
104
PFD
102(1)
AVIONICS DATA BUS
112
AHRS 2
106(2)
ADC 2
108(2)
AHRS 1
106(1)
ADC 1
108(1)
CONTROLLER
120
AVIONICS UNIT
110
ADS-B
114
TCAS
116
TIS-B
118

FIG. 1



MFD
104
PFD
102(1)
ADS-B
114
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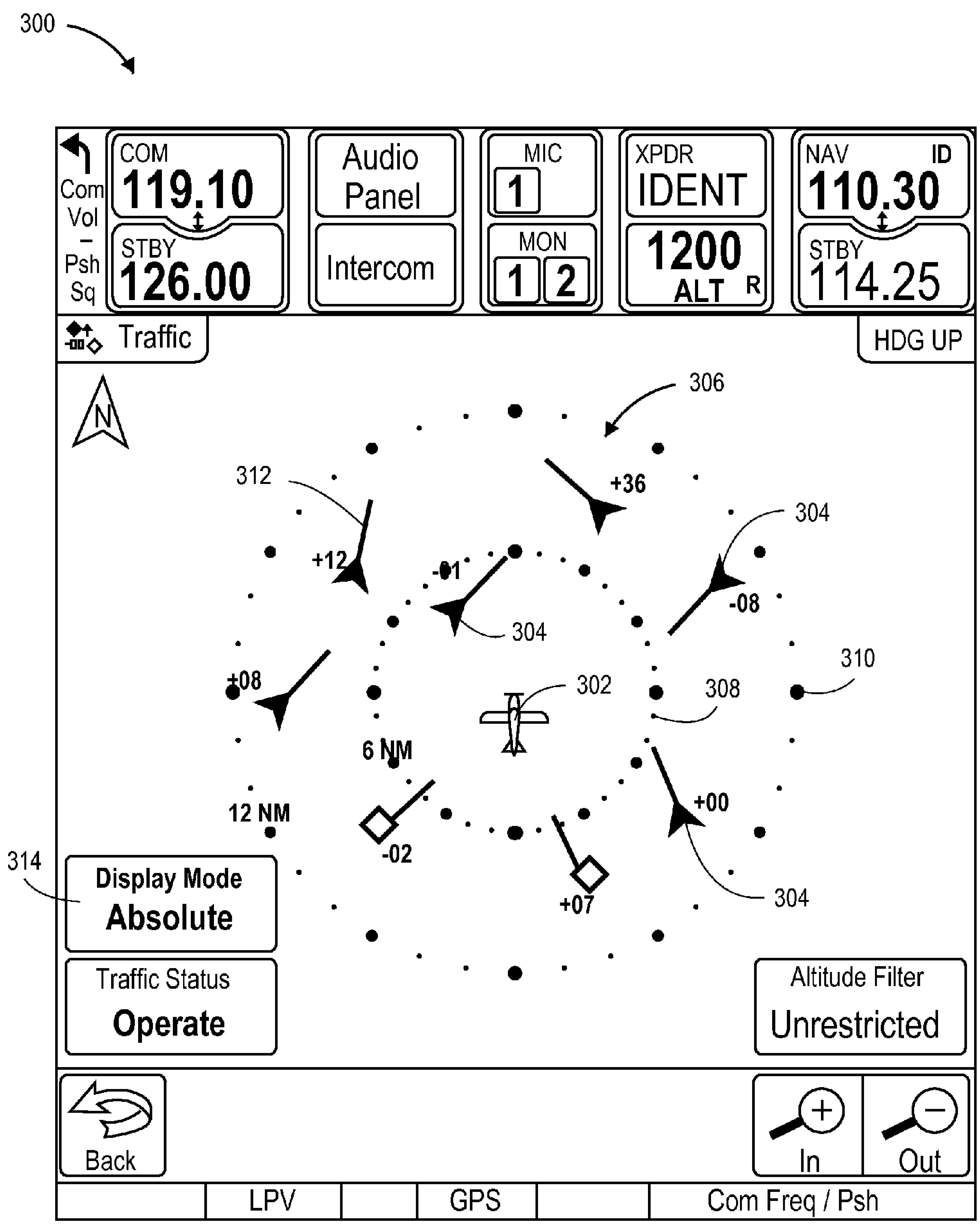
116
TIS-B
118
AHRS 1
106(1)
AHRS 2
106(2)
ADC 1
108(1)
ADC 2
108(2)
PFD
102(2)
CONTROLLER
120
AVIONICS UNIT (110)
VHF TRANSCEIVER
202
VHF NAV
204
PROCESSOR
210
GPS
206
BUS INTERFACE
208
MEMORY
212
TRAFFIC DISPLAY MODULE
214

FIG. 2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304
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+08
302
308
6 NM
12 NM
+00
-02
+07
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Traffic Status
Operate
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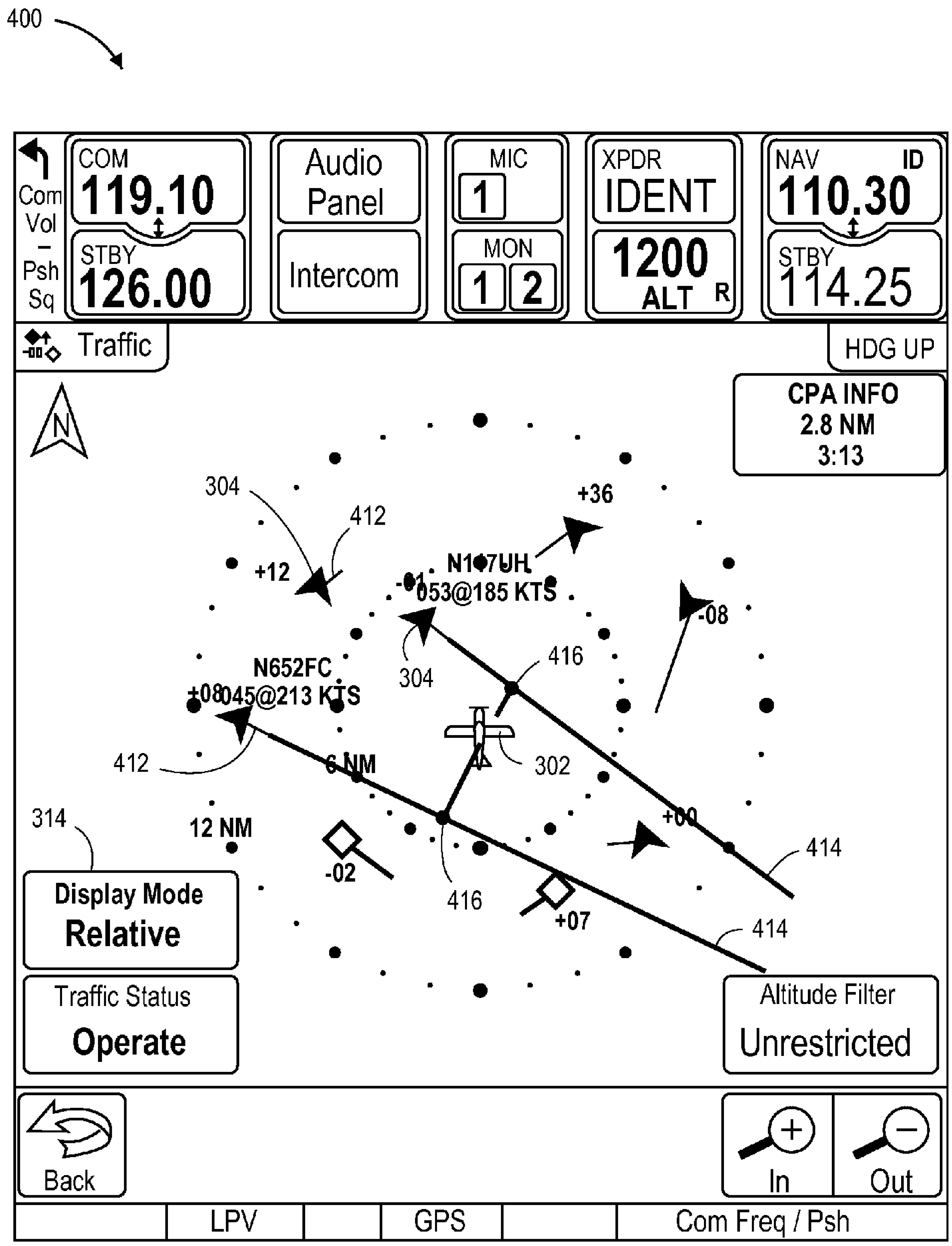
GPS
Com Freq / Psh

FIG. 3



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Traffic Status
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FIG. 4

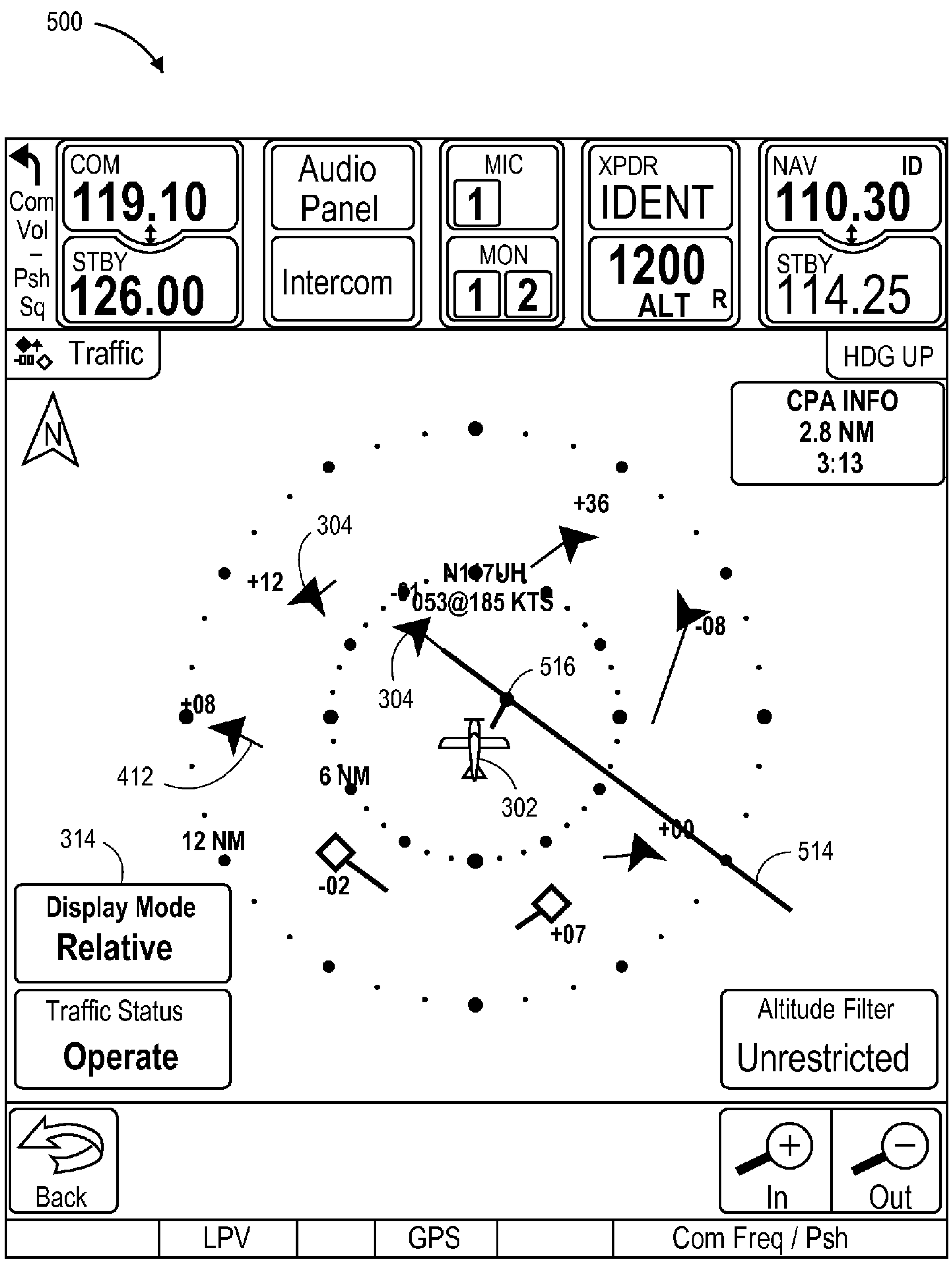

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FIG. 5

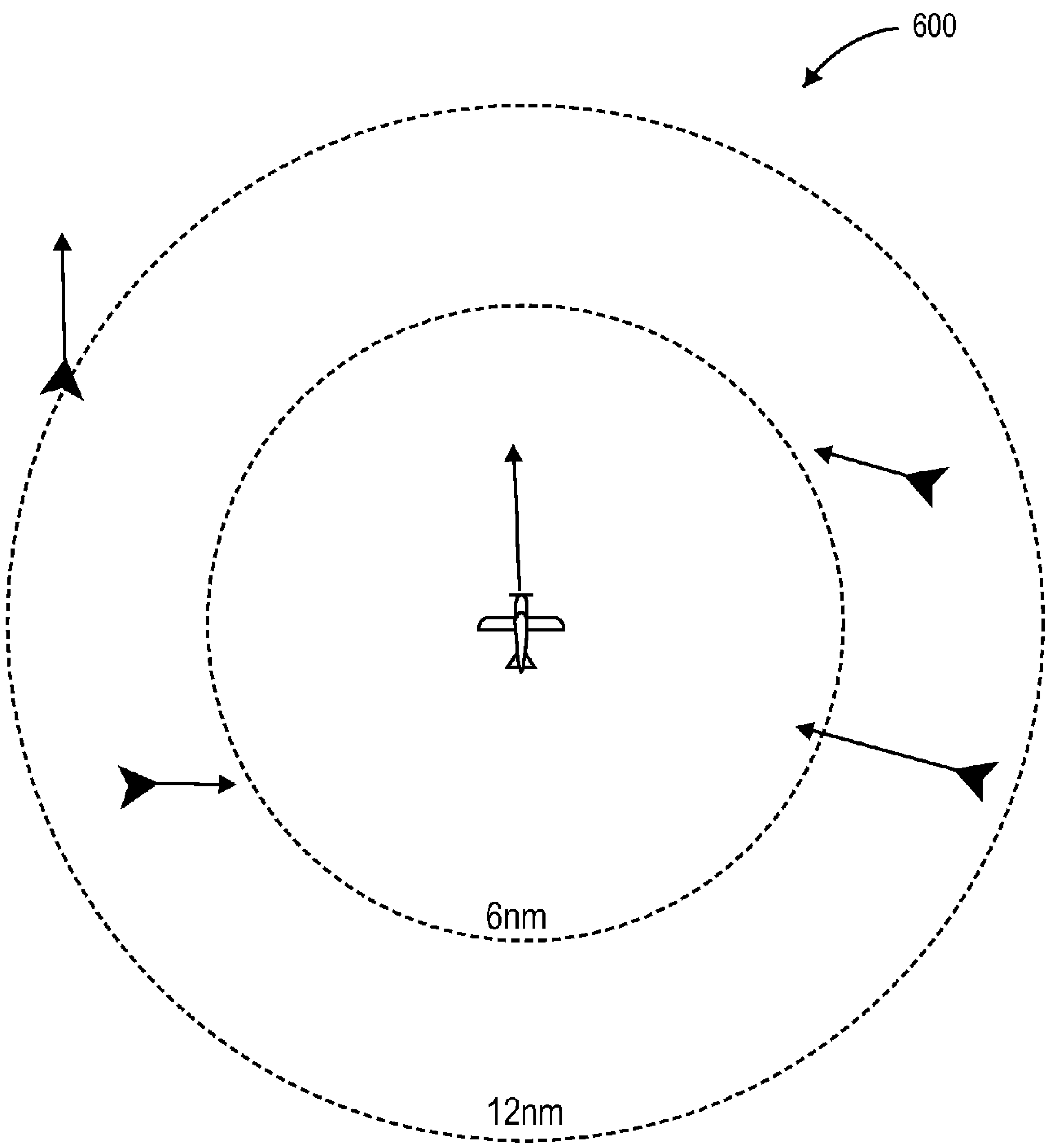


FIG. 6

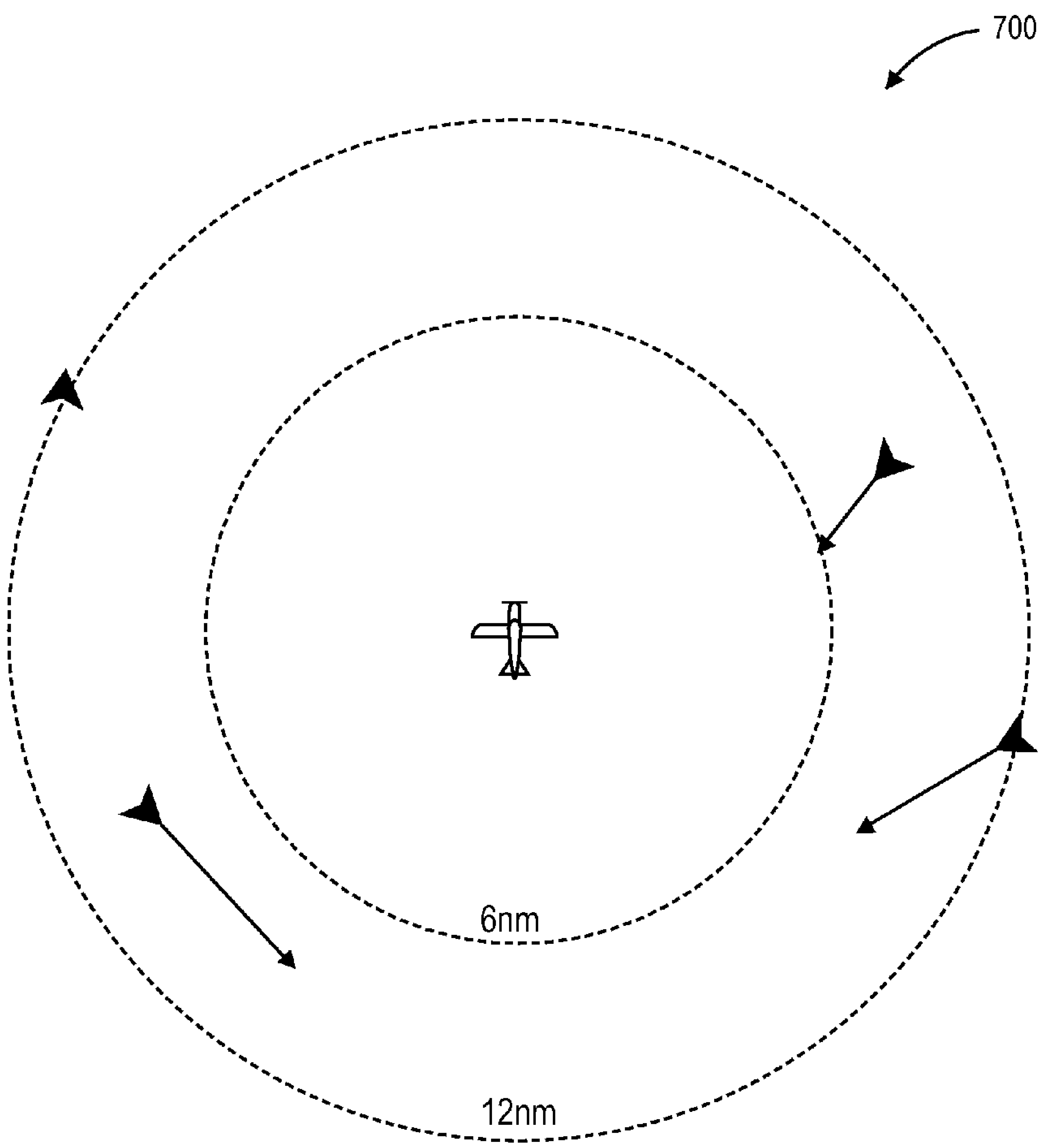
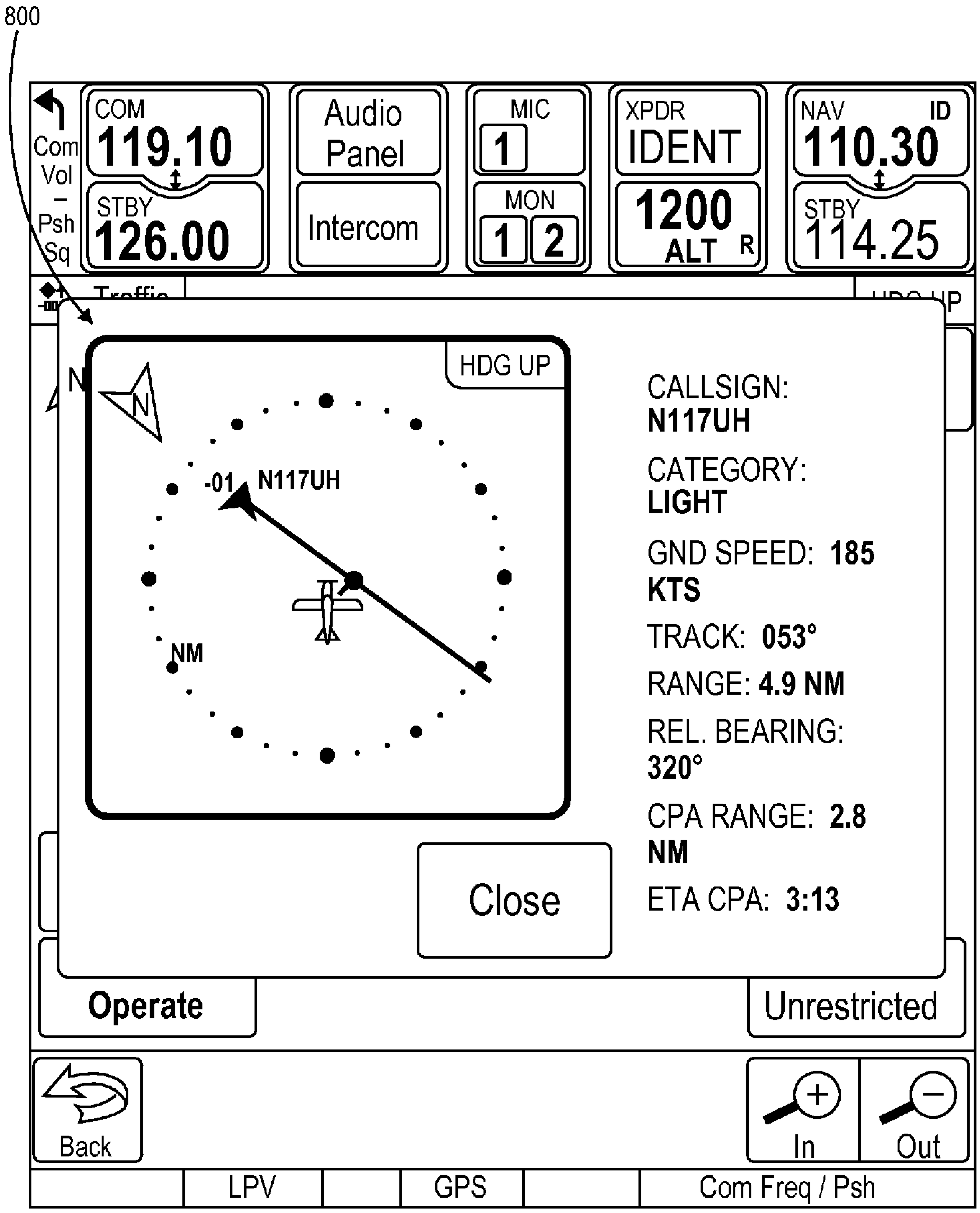


FIG. 7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-01
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NM
CALLSIGN:
N117UH
CATEGORY:
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GND SPEED: 185
KTS
TRACK: 053°
RANGE: 4.9 NM
REL. BEARING:
320°
CPA RANGE: 2.8
NM
ETA CPA: 3:13
Close
Operate
Unrestricted
Back
In
Out
LPV
GPS
Com Freq / Psh

FIG. 8

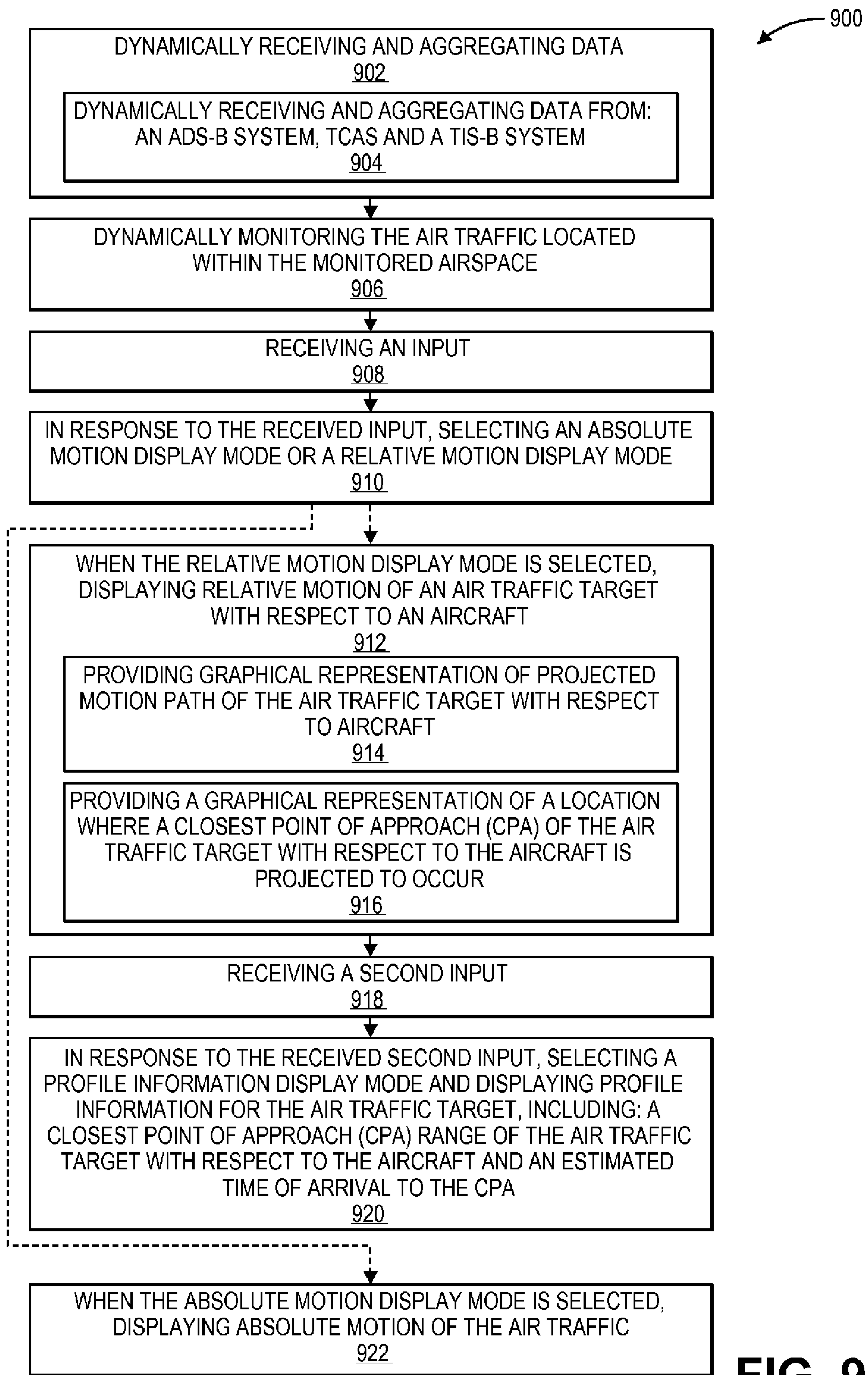
900
DYNAMICALLY RECEIVING AND AGGREGATING DATA
902
DYNAMICALLY RECEIVING AND AGGREGATING DATA FROM: AN ADS-B SYSTEM, TCAS AND A TIS-B SYSTEM
904
DYNAMICALLY MONITORING THE AIR TRAFFIC LOCATED WITHIN THE MONITORED AIRSPACE
906
RECEIVING AN INPUT
908
IN RESPONSE TO THE RECEIVED INPUT, SELECTING AN ABSOLUTE MOTION DISPLAY MODE OR A RELATIVE MOTION DISPLAY MODE
910
WHEN THE RELATIVE MOTION DISPLAY MODE IS SELECTED, DISPLAYING RELATIVE MOTION OF AN AIR TRAFFIC TARGET WITH RESPECT TO AN AIRCRAFT
912
PROVIDING GRAPHICAL REPRESENTATION OF PROJECTED MOTION PATH OF THE AIR TRAFFIC TARGET WITH RESPECT TO AIRCRAFT
914
PROVIDING A GRAPHICAL REPRESENTATION OF A LOCATION WHERE A CLOSEST POINT OF APPROACH (CPA) OF THE AIR TRAFFIC TARGET WITH RESPECT TO THE AIRCRAFT IS PROJECTED TO OCCUR
916
RECEIVING A SECOND INPUT
918
IN RESPONSE TO THE RECEIVED SECOND INPUT, SELECTING A PROFILE INFORMATION DISPLAY MODE AND DISPLAYING PROFILE INFORMATION FOR THE AIR TRAFFIC TARGET, INCLUDING: A CLOSEST POINT OF APPROACH (CPA) RANGE OF THE AIR TRAFFIC TARGET WITH RESPECT TO THE AIRCRAFT AND AN ESTIMATED TIME OF ARRIVAL TO THE CPA
920
WHEN THE ABSOLUTE MOTION DISPLAY MODE IS SELECTED, DISPLAYING ABSOLUTE MOTION OF THE AIR TRAFFIC
922

FIG. 9

DEPICTION OF RELATIVE MOTION OF AIR TRAFFIC VIA AN AIR TRAFFIC DISPLAY

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation of, and claims priority benefit to, co-pending and commonly assigned U.S. patent application entitled "DEPICTION OF RELATIVE MOTION OF AIR TRAFFIC VIA AN AIR TRAFFIC DISPLAY," application Ser. No. 13/475,666, filed May 18, 2012, which is herein incorporated by reference in its entirety.

BACKGROUND

Integrated avionics systems may include one or more electronic displays for displaying primary flight information such as attitude, altitude, heading, vertical speed, and so forth, to the pilot. For instance, integrated avionics systems may include one or more primary flight displays (PFD) and one or more multifunction displays (MFD). A representative PFD may display primary flight and selected navigation information that is typically received from one or more sensor systems such as an attitude heading reference system (AHRS), an inertial navigation system (INS), one or more air data computers (ADC) and/or navigation sensors. A representative MFD may display information for navigation and for broad situational awareness such as navigation routes, flight plans, information about aids to navigation (including airports), moving maps, weather information, terrain and obstacle information, traffic information, engine and other aircraft systems information, and so forth.

Some integrated avionics systems provide air traffic displays that are configured to display depictions of air traffic within the airspace surrounding the aircraft. In some systems, air traffic displays can display depictions of air traffic that are generated based upon data obtained from multiple air traffic detection systems, such as Traffic Collision Alerting Device (TCAD) systems, Traffic Collision Avoidance System (TCAS), Automatic Dependent Surveillance-Broadcast (ADS-B) systems, Automatic Dependent Surveillance-Re-broadcast (ADS-R) systems and Traffic Information Services-Broadcast (TIS-B) systems. In this manner, air traffic displays can be furnished that provide flight crew members with a detailed, accurate and real-time depiction of air traffic in the vicinity of the aircraft.

SUMMARY

Techniques are described that allow an air traffic display of an aircraft to display the relative motion of air traffic proximate to (e.g., within a monitored airspace around) the aircraft. In one or more implementations, the air traffic display may be switched between a first display mode in which absolute motion of air traffic is displayed (e.g., motion of air traffic targets relative to a fixed point on the earth's surface or relative to an apparently fixed celestial point is displayed) and a second display mode in which motion of air traffic targets is displayed relative to the aircraft. The techniques further facilitate the selection of one or more individual traffic targets from a displayed traffic depiction to activate a third display mode in which additional information about the relative motion of a selected target, such as its estimated closest point of approach (CPA) to the aircraft and the estimated time for it to reach the CPA are shown. The techniques may be implemented by an independent avionics unit, one or more avionics units within an integrated avionics system of the aircraft, a stand-alone air traffic display unit, and so forth.

This Summary is provided solely as an introduction to subject matter that is fully described in the Detailed Description and Drawings. The Summary should not be considered to describe essential features nor be used to determine the scope of the Claims. Moreover, it is to be understood that both the foregoing Summary and the following Detailed Description are example and explanatory only and are not necessarily restrictive of the subject matter claimed.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

The detailed description is described with reference to the accompanying figures. The use of the same reference numbers in different instances in the description and the figures may indicate similar or identical items.

FIG. **1** is a block diagram illustrating an environment in an example implementation that includes an integrated avionics system configured to provide an air traffic display in accordance with the present disclosure.

FIG. **2** is a block diagram illustrating an avionics unit of the integrated avionics system shown in FIG. **1**, wherein the avionics unit is configured to cause an air traffic display displayed by a display device of the integrated avionics system to display the motion of air traffic targets relative to the aircraft.

FIG. **3** is an illustration depicting an example air traffic display, wherein the air traffic display has been configured to display graphical indicators depicting absolute motion of a plurality of aircraft within a monitored airspace in accordance with an example implementation of the present disclosure.

FIG. **4** is an illustration depicting an example air traffic display, wherein the air traffic display has been configured to display graphical indicators depicting relative motion of the plurality of aircraft within the monitored airspace in accordance with an example implementation of the present disclosure.

FIG. **5** is an illustration depicting the example air traffic display shown in FIG. **4**, wherein the air traffic display has further been configured to display a graphical indicator depicting an estimated closest point of approach (CPA) of an aircraft within the monitored airspace in accordance with an example implementation of the present disclosure.

FIGS. **6** and **7** are diagrams illustrating absolute motion and relative motion, respectively, of aircraft and air traffic targets within a monitored airspace.

FIG. **8** is an illustration depicting a display that includes detailed profile information for an aircraft selected from the air traffic displays shown in FIGS. **4** and **5**, in accordance with a further example implementation of the present disclosure.

FIG. **9** is a flow diagram illustrating a process in an example implementation in which an air traffic display of an aircraft may be configured to display the relative motion and absolute motion of air traffic proximate to the aircraft.

The drawing figures do not limit the system to the specific implementations disclosed and described herein. The drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating elements of the system.

DETAILED DESCRIPTION

Overview

Currently, airborne air traffic displays show directionality information (e.g., heading, position, threat level, etc.) for air traffic targets that is based upon data which measures how those air traffic targets are moving relative to the ground (e.g., ground-based track data, ground track data, ground track, true track, etc.). Consequently, to determine if the displayed air traffic targets may pose a threat of collision with the aircraft, the flight crew must monitor the changing position of the targets to determine whether the air traffic targets are moving toward the aircraft or away from the aircraft. For example, a pilot may periodically monitor the position of an air traffic target within an air traffic display to determine whether the air traffic target is moving left to right or right to left across the air traffic display or downward on the air traffic display. The pilot may determine whether the air traffic target poses a threat of colliding with the aircraft based on the current position of the air traffic target, its direction of travel (e.g., heading), and its speed. If the current position, direction of travel, and speed of the air traffic target overlap or intersect with a future position of the aircraft, the target could potentially pose a threat of collision. Flight crew members therefore must spend time monitoring the air traffic display in an effort to identify air traffic target threats, rather than looking outside of the aircraft's cockpit (e.g., practicing "see and avoid" techniques) or focusing on other displays and instrumentation.

Accordingly, techniques are described that allow an air traffic display of an aircraft to display the relative motion of air traffic proximate to (e.g., within a monitored airspace around) the aircraft. In one or more implementations, the techniques may be implemented by (e.g., as one or more software modules executed by) an avionics unit, which may be part of an integrated avionics system of the aircraft (e.g., an integrated avionics unit (IAU)), display devices, one or more dedicated air traffic display units, a combination thereof, and so forth. The avionics unit is configured to cause a display device to furnish an air traffic display within the cockpit of the aircraft to be switched between a first display mode in which absolute motion of air traffic is displayed (e.g., motion of air traffic targets relative to a fixed point on the earth's surface or relative to an apparently fixed celestial point is displayed) and a second display mode in which motion of air traffic targets is displayed relative to the aircraft. The avionics unit may determine the relative motion of the one or more air traffic targets or receive information providing the relative motion of air traffic targets within a monitored airspace surrounding the aircraft. The avionics unit may further facilitate the selection of individual air traffic targets from a displayed traffic depiction to activate a third display mode in which additional information about the selected target, such as its estimated closest point of approach (CPA) to the aircraft and the estimated time it will take the selected target to reach the CPA are shown. The additional information may be profile information that may include relative motion information for the selected target. Thus, the avionics unit, amongst other functionality, can allow for leveraging of different presentations of air traffic to a flight crew.

The avionic unit may determine information about air traffic within a monitored airspace surrounding the aircraft and/or potential maneuvers for avoiding a collision with an air traffic target. In embodiments, the techniques described herein may employ vector mathematics, and may leverage data that is calculated for use in Conflict Situational Awareness (CSA) algorithms, to determine (e.g., infer or estimate) information about air traffic targets such as: direction of travel (track), speed, how close the targets may pass relative to the aircraft (e.g., Closest Point of Approach (CPA)), how long before a CPA will occur, potential maneuvers for increasing the distance of the CPA, and potential maneuvers for avoiding collision. Further, the techniques allow for air traffic display depictions to be displayed that show motion of each air traffic target (e.g., each of a plurality of other aircraft within a monitored airspace surrounding the aircraft) relative to the aircraft. Still further, the techniques allow a flight crew member (e.g., pilot or copilot) to selectively switch between a first display mode (in which absolute motion of air traffic is displayed) and a second display mode (in which motion of air traffic targets relative to aircraft is displayed) on an air traffic display (e.g., a Cockpit Display of Traffic Information (CDTI) display). The flight crew member may select individual traffic targets from a displayed traffic depiction to activate a third display mode (in which additional information about the selected target, such as its estimated CPA to the aircraft and the estimated time it will take the selected target to reach the CPA, are shown). The additional information may include profile information that may include relative motion information for the selected target. In some embodiments, the CPA for target aircraft may be displayed by the first display mode and/or the second display mode.

The above-referenced functionality, which is described in more detail herein, promotes situation awareness by allowing a pilot, with a single glance at an air traffic display, to quickly determine the relative and/or absolute motion of nearby traffic. The integrated avionics system described herein may be utilized to determine maneuvers required to maintain a certain distance from an air traffic target. In implementations, the distance maintained from an air traffic target, which may be automatically determined or selected by a user, may be specified by a user or determined based on the various criteria (e.g., the size of aircraft, the current velocity of the aircraft, a pilot-specified parameter, a predetermined default distance, etc.).

Moreover, in implementations, the techniques described herein may be utilized to promote situational awareness during in-trail approach scenarios, traffic join-up scenarios, Civil Air Patrol (CAP) applications, Search and Rescue (SAR) applications, and in situations where it is desirable to monitor separation while on approach with dissimilar categories of aircraft.

Example Environment

FIG. **1** illustrates an environment in an example implementation that includes an integrated avionics system **100** configured to provide an air traffic display in accordance with various techniques of the present disclosure. The integrated avionics system **100** may include one or more primary flight displays (PFDs) **102**, and/or one or more multifunction displays (MFD) **104**.

For instance, in the implementation illustrated in FIG. **1**, the integrated avionics system **100** may be configured for use in an aircraft that is flown by a flight crew having two pilots (e.g., a pilot and a co-pilot). In this implementation, the integrated avionics system **100** may include a first PFD **102(1)**, a second PFD **102(2)**, and an MFD **104** that are mounted in the aircraft's instrument panel. As shown, the MFD **104** is mounted generally in the center of the instrument panel so that it may be accessed by either pilot (e.g., by either the pilot or the copilot). The first PFD **102(1)** is mounted in the instrument panel generally to the left of the MFD **104** for viewing and access by the pilot. Similarly, the second PFD **102(2)** is mounted in the instrument panel generally to the right of the MFD **104** for viewing and access by the aircraft's copilot or other crew member or passenger.

The PFDs **102** may be configured to display primary flight information, such as aircraft attitude, altitude, heading, vertical speed, and so forth. In implementations, the PFDs **102** may display primary flight information via a graphical representation of basic flight instruments such as an attitude indicator, an airspeed indicator, an altimeter, a heading indicator, a course deviation indicator, and so forth. The PFDs **102** may also display other information providing situational awareness to the pilot such as terrain information and ground proximity warning information.

As shown in FIG. **1**, primary flight information may be generated by one or more flight sensor data sources including, for example, one or more attitude, heading, angular rate, and/or acceleration information sources such as attitude and heading reference systems (AHRSs) **106**, one or more air data information sources such as air data computers (ADCs) **108**, and/or one or more angle of attack information sources. For instance, in one implementation, the AHRSs **106** may be configured to provide information such as attitude, rate of turn, slip and skid; while the ADCs **108** may be configured to provide information including airspeed, altitude, vertical speed, and outside air temperature. Other configurations are possible.

One or more avionics units **110** (e.g., a single integrated avionics unit (IAU) is illustrated) may aggregate the primary flight information from the AHRSs **106** and ADCs **108** and provide the information to the PFDs **102** via an avionics data bus **112**. The avionics unit **110** may also function as a combined communications and navigation radio. For example, as shown in FIG. **2**, the avionics unit **110** may include a two-way Very High Frequency (VHF) communications transceiver **202**, a VHF navigation receiver with glide slope **204**, a global navigation satellite system (GNSS) receiver such as a global positioning system (GPS) receiver **206**, or the like, an avionics data bus interface **208**, a processor **210**, a memory **212** including a traffic display module **214**, and so forth.

The processor **210** provides processing functionality for the avionics unit **110** and may include any number of processors, micro-controllers, or other processing systems and resident or external memory for storing data and other information accessed or generated by the avionics unit **110**. The processor **210** may execute one or more software programs which implement techniques described herein. The processor **210** is not limited by the materials from which it is formed or the processing mechanisms employed therein, and as such, may be implemented via semiconductor(s) and/or transistors (e.g., electronic integrated circuits (ICs)), and so forth.

The memory **212** is an example of computer-readable media that provides storage functionality to store various data associated with the operation of the avionics unit **110**, such as the software programs and code segments mentioned above, or other data to instruct the processor **210** and other elements of the avionics unit **110** to perform the functionality described herein. Although a single memory **212** is shown, a wide variety of types and combinations of memory may be employed. The memory **212** may be integral with the processor **210**, stand-alone memory, or a combination of both. The memory **212** may include, for example, removable and non-removable memory elements such as RAM, ROM, Flash (e.g., SD Card, mini-SD card, micro-SD Card), magnetic, optical, USB memory devices, and so forth.

The avionics data bus interface **208** furnishes functionality to enable the avionics unit **110** to communicate with one or more avionics data buses such as the avionics data bus **112**. In various implementations, the avionics data bus interface **208** may include a variety of components, such as processors, memory, encoders, decoders, and so forth, and any associated software employed by these components (e.g., drivers, configuration software, etc.).

As shown in FIG. **1**, the integrated avionics unit **110** may be paired with a primary flight display (PFD) **102**, which may function as a controlling unit for the integrated avionics unit **110**. In implementations, the avionics data bus **112** may comprise a high speed data bus (HSDB), such as data bus complying with ARINC 429 data bus standard promulgated by the Airlines Electronic Engineering Committee (AEEC), a MIL-STD-1553 compliant data bus, and so forth.

The MFD **104** displays information describing operation of the aircraft such as navigation routes, moving maps, engine gauges, weather radar, ground proximity warning system (GPWS) warnings, traffic collision avoidance system (TCAS) warnings, airport information, and so forth, that are received from a variety of aircraft systems via the avionics data bus **112**. Information displayed on MFD **104** may be displayed on a PFD **102** and that the information displayed on a PFD **102** may be displayed on MFD **104**. In embodiments, the integrated avionics system **100** may include only a single display device (e.g., a PFD **102** or a MFD **104**).

In implementations, the integrated avionics system **100** employs redundant sources of primary flight information to assure the availability of the information to the pilot, and to allow for cross-checking of the sources of the information. For example, the integrated avionics system **100** illustrated in FIG. **1** employs two PFDs **102** that may receive primary flight information from redundant AHRSs **106** and ADCs **108**, via the avionics unit **110**. The integrated avionics system **100** is configured so that the first PFD **102**(**1**) receives a first set of primary flight information aggregated by the avionics unit **110** from a first AHRS **106**(**1**) and ADC **108**(**1**). Similarly, the second PFD **102**(**2**) receives a second set of primary flight information aggregated by the avionics unit **110** from a second AHRS **106**(**2**) and ADC **108**(**2**). Additionally, although a single avionics unit **110** and a single avionics data bus **112** are illustrated in FIG. **1**, it is contemplated that redundant IAU's and/or redundant data buses may be employed for communication between the various components of the integrated avionics system **100**.

In implementations, primary flight information provided by either the first AHRS **106**(**1**) and ADC **108**(**1**) or the second AHRS **106**(**2**) and ADC **108**(**2**) may be displayed on either PFD **102**(**1**) or **102**(**2**), or on the MFD **104** upon determining that the primary flight information received from either AHRS **106** and ADC **108** is in error or unavailable. One or both of the PFDs **102** may also be configured to display information shown on the MFD **104** (e.g., engine gauges and navigational information), such as in the event of a failure of the MFD **104**.

The integrated avionics system **100** may employ cross-checking of the primary flight information (e.g., attitude information, altitude information, etc.) to determine if the primary flight information to be furnished to either of the PFDs **102** is incorrect. In implementations, cross-checking may be accomplished through software-based automatic continual comparison of the primary flight information provided by the AHRS **106** and ADC **108**. In this manner, a "miss-compare" condition can be explicitly and proactively annunciated to warn the pilot when attitude information displayed by either PFD **102** sufficiently disagrees.

The first PFD **102**(**1**), the second PFD **102**(**2**), and/or the MFD **104** may receive additional data aggregated by the avionics unit **110** from a one or more of a plurality of systems communicatively coupled with the avionics unit

110. For example, the avionics unit **110** may be communicatively coupled with and may aggregate data received from one or more of: an Automatic Dependent Surveillance-Broadcast (ADS-B) system **114**, Traffic Collision Avoidance System (TCAS) **116**, and a Traffic Information Services-Broadcast (TIS-B) system **118**.

One or more of the displays PFD **102(1)**, PFD **102(2)**, MFD **104** of the integrated avionics system **100** may be one of: an LCD (Liquid Crystal Diode) display, a TFT (Thin Film Transistor) LCD display, an LEP (Light Emitting Polymer or PLED (Polymer Light Emitting Diode) display, a cathode ray tube (CRT) and so forth, capable of displaying text and graphical information. Further, one or more of the displays PFD **102(1)**, PFD **102(2)**, MFD **104** may be backlit via a backlight such that it may be viewed in the dark or other low-light environments.

The integrated avionics system **100** may include a controller **120** which communicates with the avionics data bus **112**. The controller **120** may provide a user interface (e.g., a touch interface) for the pilot for controlling the functions of one or more of the displays PFD **102(1)**, PFD **102(2)**, MFD **104** and for inputting information, such as navigational data, into the integrated avionics system **100**. The avionics unit **110** may be configured for aggregating data and/or operating in an operating mode selected from a plurality of user-selectable operating modes based upon inputs provided via the controller **120**.

The avionics unit **110** may be configured to generate an air traffic display based upon the data that it receives and aggregates from the various systems, such as the ADS-B system **114** and the TCAS **116**. The air traffic display may depict air traffic within a monitored airspace surrounding the aircraft. For example, the avionics unit **110** is illustrated as including a traffic display module **214** which is storable in memory **212** and executable by the processor **210**. The traffic display module **214** is representative of mode of operation selection and control functionality to access the received data (e.g., air traffic data) and generate an air traffic display based upon the received and aggregated data. The generated air traffic display may then be provided to and displayed by one or more of the display device(s) (e.g., PFD **102(1)**, PFD **102(2)**, or MFD **104**).

Examples of the displayed, generated air traffic displays (e.g., screenshots of the air traffic displays) are shown in FIGS. **3**, **4**, and **5**. The air traffic displays may provide graphical depictions of air traffic that is located within a monitored airspace proximal to the aircraft in which the integrated avionics system **100** is implemented (e.g., in a three dimensional vicinity surrounding the aircraft, which may be pre-determined or selectable by a flight crew member). For instance, in FIGS. **3**, **4** and **5**, air traffic displays **300**, **400**, and **500** provide a graphical (e.g., iconic) representation of the aircraft (e.g., the flight crew's ownship) **302** as a fixed central reference or focal point, while also showing graphical and/or iconic representations of other aircraft (e.g., air traffic targets) **304** located within a monitored airspace **306** (e.g., monitored airspace surrounding the aircraft **302**). In the implementations shown, the monitored airspace **306** covers up to a 12 nautical mile radius around the aircraft **302**. However, a larger or smaller monitoring area (e.g., the area covered by the monitored airspace) may be determined or selected to monitor a larger or smaller area as desired. Further, the air traffic displays **300**, **400**, **500** provide boundary markers (e.g., concentric rings **308**, **310**) for demarcating sub-zones within the monitored airspace. For instance, in FIGS. **3**, **4**, and **5**, concentric rings **308**, **310** are provided to demarcate a 6 nautical mile radius and a 12 nautical mile radius, respectively, around the aircraft **302**.

As mentioned above, the avionics unit **110** may be configured to aggregate data and/or operate in an operating mode (e.g., display mode) selected from a plurality of operator-selectable operating modes based upon inputs provided via the controller **120**. For example, the avionics unit **110** may be placed into a first operating mode via the provided input(s). In embodiments the first operating mode is an absolute display mode, in which the avionics unit **110** aggregates data and provides an air traffic display comprised of a software-generated depiction to the display device(s) (e.g., PFD **102(1)**, PFD **102(2)**, or MFD **104**) which, when displayed, depicts absolute motion of air traffic within the monitored airspace **306** proximate to the aircraft **302**.

FIG. **3** illustrates an air traffic display **300** in which graphical depictions (e.g., absolute motion lines or vectors) **312** illustrating the absolute motion of air traffic targets (e.g., other aircraft) **304** within the monitored vicinity or airspace **306** of the aircraft **302** is shown. Absolute motion may be defined as motion relative to a fixed point on the earth's surface or relative to an apparently fixed celestial point.

FIG. **6** illustrates an example depiction **600** of absolute motion for a set of aircraft. In FIG. **6**, a centrally-located aircraft is depicted along with a plurality of air traffic targets in an air traffic zone, with the air traffic targets generally shown as surrounding the aircraft. Directional vectors for the aircraft and each of the air traffic targets are provided in FIG. **6** in order to illustrate the absolute motion of the air traffic targets and the aircraft (e.g., the motion of both the air traffic targets and the aircraft relative to a fixed point on the earth's surface or relative to an apparently fixed celestial point). In embodiments, the absolute motion of an air traffic target may include the current position of the air traffic target and an indication of an expected travel path (e.g., absolute motion lines or vectors) determined from a current direction of travel (e.g., heading) and speed. CPA for one or more of the target aircraft may be displayed along with target aircraft position and vector.

In another example, the avionics unit **110** may be switched out of the first operating mode and/or placed into a second operating mode included in the plurality of user-selectable operating modes, the second operating mode being a relative display mode. In some configurations, the avionics unit **110** may automatically toggle between the first and second operating modes. In other configurations, the operating modes may be directed switched by the crew or switched by the avionics unit **110** in response to a crew input. In second operating mode (relative display mode), the avionics unit **110** aggregates data and provides an air traffic display comprised of a software-generated depiction to one or more display device(s) (e.g., PFD **102(1)**, PFD **102(2)**, or MFD **104**) which, when displayed, depicts relative motion of air traffic within the monitored airspace **306** of the aircraft **302** (e.g., relative motion of the other aircraft with respect to the aircraft **302**). In some embodiments, the avionics unit may be configured to cause the air traffic display in a first operating mode and a second operating mode to be simultaneously displayed on one or more display devices.

FIGS. **4** and **5** illustrate air traffic displays **400**, **500** in which graphical depictions (e.g., relative motion lines or vectors) **412** are shown illustrating relative motion of the air traffic targets (e.g., other aircraft) **304** within the monitored airspace **306** (e.g., vicinity, area) with respect to the aircraft **302**. Relative motion may be defined as the movement of one or more contacts (e.g., air traffic targets **304**) with respect to the aircraft (e.g., the aircraft **302**).

FIG. 7 illustrates, for the air traffic targets and the aircraft having the absolute motion profiles shown in FIG. 6, an example view 700 of the corresponding relative motion for those air traffic targets with respect to the centrally-depicted reference aircraft. Directional vectors for each of the air traffic targets provided in FIG. 7 illustrate the relative motion of the air traffic targets relative to the aircraft (e.g., the motion of the air traffic targets relative to the aircraft).

Air traffic displays **400**, **500** further include graphical representations of projected (e.g., estimated future) motion path(s) of one or more of the air traffic targets **304** relative to the aircraft **302** based upon the current determined speeds (e.g., velocities) and directions of travel (e.g., heading) of the air traffic target(s) **304** and the aircraft **302**. Projecting the future movement and proximity of two objects (e.g., aircraft) may involve the assumption that the current velocity and direction of travel of both objects will remain constant. In embodiments, the projected motion path may be based on the current velocity and direction of travel and a historical velocity and direction of travel. For example, if the speed of aircraft **302** or air traffic target(s) **304** is changing (e.g., increasing or decreasing), the protected motion path may include an assumption that the rate of speed change will continue for a period of time or anticipated speed. In embodiments, the protected motion path may be based on geographic data such as airports, no-fly zones, flight plans, and other location information that may impact the path of travel of an aircraft.

Further, the air traffic displays **400**, **500** may provide graphical representations of a projected or estimated closest point(s) of approach (CPA) for one or more of the air traffic targets (e.g., other aircraft) **304** relative to the aircraft **302**. As shown in FIGS. **4** and **5**, projected path lines or vectors **414**, **514** may be extrapolated (e.g., may extend) from relative motion lines **412** to determine and show projected future paths of the air traffic targets (e.g., other aircraft) **304**. Further, the air traffic displays **400**, **500** illustrated in FIGS. **4** and **5** may also show points or locations **416**, **516** within the monitored airspace **306** where CPAs are estimated to occur.

In embodiments, projected path lines **414** and estimated CPA locations **416** may be indicated for air traffic targets **304** which are located within a nearer sub-zone **308** and also, for air traffic targets **304** located within a more distant sub-zone **310** of the monitored airspace **306** relative to the aircraft **302**. In one mode, as shown in FIG. **4**, estimated CPA locations **416** are within nearer sub-zone **308** with varying distances within the nearer sub-zone **308**. In another mode, as shown in FIG. **5**, projected path lines **514** and estimated CPA locations **516** may instead just be shown for aircraft within a nearer sub-zone **308** relative to the aircraft **302** that is determined to pose a higher risk of collision.

The air traffic displays **300**, **400**, **500** may provide graphical (e.g., iconic and/or textual) indicators indicating the operational mode (e.g., display mode) which is currently activated. These operational (display) mode indicators may be provided in the form of a display mode text box **314** as shown. Further, as shown in FIGS. **4** and **5**, aircraft data indicators for the air traffic targets **304** may be provided in the form of textual information listed next to the air traffic target (other aircraft) **304** icons in the air traffic displays **400**, **500** and may provide data such as: callsign or identifier of an air traffic target **304**, ground speed of an air traffic target **304**, track data of the air traffic target **304**, and any other information associated with the air traffic target **304**.

In one or more implementations, the avionics unit **110** may be switched out of the first or second operating modes and/or placed into a further operating mode included in the plurality of user-selectable operating modes, the further operating mode being a selected aircraft profile display mode. In a selected aircraft profile display mode, the avionics unit **110** aggregates data and provides a an air traffic display comprised of a software-generated depiction to the display device(s) (e.g., PFD **102(1)**, PFD **102(2)**, or MFD **104**) which, when displayed, depicts detailed profile information from an air traffic target (e.g., another aircraft) **304** selected from one of the displayed air traffic displays **300**, **400** or **500**, such as those shown in FIGS. **3**, **4**, and **5**. For example, from a displayed air traffic display **300**, **400**, **500**, an operator (e.g., member of the aircraft's flight crew such as a pilot or copilot) may provide an input for selecting one of the displayed air traffic targets (e.g., other aircraft) **304** and requesting more detailed or additional profile information corresponding to the selected air traffic target **304**. This input may, for example, be provided via touch input to the controller **120**, a control (e.g., knob, button, etc.) within the integrated avionics system **100**, and so forth. However, the profile information may be presented by any of the operating modes.

FIG. **8** illustrates a display **800** in which detailed profile information (e.g., shown in a textual format) is depicted for a selected air traffic target **304**. As shown, the detailed profile information may include, but is not limited to, the following data corresponding to the selected air traffic target **304**: a callsign or identifier; a weight class category; a ground speed; track data; range data; relative bearing; a closest point of approach (CPA) range relative to the aircraft **302**; and an estimated time of arrival to a CPA. The display **800** may be provided as an overlay window to one of air traffic displays **300**, **400**, **500**, and may be closed (removed from display) via a second input.

The avionics unit **110** is configured for dynamically aggregating data and for providing air traffic display(s) comprised of dynamically-updated software-generated depictions to one or more display device(s) (e.g., PFD **102(1)**, PFD **102(2)**, or MFD **104**) based upon the dynamically aggregated and updated data for the aircrew (e.g., pilot and/or copilot) of the aircraft **302** with a real-time view of traffic data within the monitored airspace **306** surrounding the aircraft **302**.

Generally, any of the functions described herein can be implemented using software, firmware, hardware (e.g., fixed logic circuitry), manual processing, or a combination of these implementations. The terms "module" and "functionality" as used herein generally represent software, firmware, hardware, or a combination thereof. The communication between modules in the integrated avionics system **100** of FIG. **1** and/or the avionics unit **110** of FIG. **2** can be wired, wireless, or some combination thereof. In the case of a software implementation, for instance, the module represents executable instructions that perform specified tasks when executed on a processor, such as the processor **210** of the avionics unit **110** shown in FIG. **2**. The program code can be stored in one or more storage media, an example of which is the memory **212** associated with the avionics unit **110** of FIG. **2**. While an integrated avionics system **100** is described herein, by way of example, it is contemplated that, the functions described herein can also be implemented in one or more independent (stand-alone) avionics units or systems implemented within an aircraft, such as an aircraft that does not include an integrated avionics system.

Example Procedures

The following discussion describes procedures that allow an air traffic display of an aircraft to determine and display the relative motion and/or absolute motion of air traffic proximate to (e.g., within a monitored airspace around) the aircraft. For example, motion information (including closest point of approach (CPA) information) for air traffic relative to the aircraft may be provided to a display device and displayed within an air traffic display in a first display mode, and absolute motion of the air traffic may be provided to the display device and displayed within an air traffic display in a second display mode. Aspects of the procedures may be implemented in hardware, firmware, or software, or a combination thereof. The procedures are shown as a set of blocks that specify operations performed by one or more devices and are not necessarily limited to the orders shown for performing the operations by the respective blocks. In portions of the following discussion, reference will be made to the integrated avionics system **100** of FIG. **1**, the avionics unit **110** of FIG. **2**, the air traffic displays of FIGS. **3**, **4**, and **5**, and the display **800** of FIG. **8**.

FIG. **9** illustrates a procedure **900**, in an example implementation, in which an integrated avionics system **100** implemented on-board an aircraft may be selectively switched between a first display mode in which absolute motion of air traffic targets is determined and displayed (e.g., motion of the air traffic targets relative to a fixed point on the earth's surface or relative to an apparently fixed celestial point is displayed) and a second display mode in which motion of air traffic targets relative to the aircraft is determined and displayed. The depicted air traffic targets are located within a monitored airspace surrounding the aircraft. As illustrated, the procedure **900** may include dynamically receiving and aggregating data (Block **902**) describing both the location and velocity of air traffic targets (e.g., other aircraft) within the monitored airspace and the location and velocity of the aircraft. The term "air traffic" as used herein may include both an aircraft and air traffic targets in the monitored airspace surrounding the aircraft. For example, an avionics unit **110** (e.g., an integrated avionics unit (IAU) of an integrated avionics system **100**) within the aircraft may dynamically receive and aggregate data from one or more systems, such as an ADS-B system **114**, a TCAS **116**, a GPS system **206**, a controller **120**, and/or a TIS-B system **118**, and so forth (Block **904**), which are communicatively coupled with the avionics unit **110** via an avionics data bus **112**. Air traffic within a monitored vicinity of the aircraft is dynamically monitored (Block **906**). For example, the avionics unit **110** dynamically monitors air traffic targets **304** located within the monitored airspace surrounding the aircraft **302** and also monitors the aircraft **302** based upon the dynamically received and aggregated data.

An input is then received (Block **908**) to select one of a first display mode or a second display mode for the air traffic display. For example, the avionics unit **110** may receive a first input from a member of the flight crew (e.g., pilot and/or copilot) provided via a user interface, such as via a controller **120**. The received input may also comprise a non-user (e.g., flight crew) provided input that is automatically provided by one or more components of the integrated avionics system **100**. In response to the received input, one of: the first display mode (e.g., absolute motion display mode) or the second display mode (e.g., relative motion display mode) is selected (Block **910**). For example, based upon the received input, the avionics unit **110** may then provide an air traffic display comprised of a software-generated depiction to one or more of the display device(s) (e.g., PFD **102**(**1**), PFD **102**(**2**), or MFD **104**) implemented on-board the aircraft.

If the received input selects the second display mode to determine and/or display the relative motion display mode (Block **912**), the avionics unit **110** may then provide an air traffic display comprised of a software-generated depiction to one or more of the display device(s) (e.g., PDF **102**(**1**), PDF **102**(**2**), or MFD **104**). For example, the air traffic display(s) comprised of software-generated depictions **400**, **500**, such as shown in FIGS. **4** and **5**, may provide a graphical indication of the motion of air traffic targets **304** relative to aircraft **302**. The avionics unit **110** may determine the relative motion of the one or more air traffic targets or receive information providing the relative motion of air traffic targets within a monitored airspace surrounding the aircraft. The air traffic display(s) comprised of software-generated depictions **400**, **500** may be generated by the avionics unit **110** based upon the data which was dynamically received and aggregated by the avionics unit **110**. For example, motion of the air traffic targets **304** relative to aircraft **302** may be shown by relative motion indicators **412**. Further, a graphical representation of a projected motion path(s) **414** of the air traffic targets **304** relative to aircraft **302** may be determined and shown, the projected motion path(s) being based upon positions, velocities and directions of travel (e.g., heading) of air traffic targets **304** and aircraft **302** (Block **914**). Still further, a location **416** where a closest point of approach (CPA) of the air traffic targets **304** relative to aircraft **302** is projected to occur may also be determined and a graphical representation of the location **416** shown (Block **916**).

If the received input selects the first display mode to determine and/or display the absolute motion display mode (Block **922**), the avionics unit **110** may then provide an air traffic display comprised of a software-generated depiction to one or more of the display device(s) (e.g., PDF **102**(**1**), PDF **102**(**2**), or MFD **104**). The air traffic display comprised of the software-generated depiction **300**, such as shown in FIG. **3**, may provide a graphical indication of absolute motion of the air traffic targets **304** and aircraft **302**. The air traffic display comprised of the software-generated depiction **300** may be generated by the avionics unit **110** based upon the data which was dynamically received and aggregated by the avionics unit **110**.

The avionics unit **110** may receive a second input (Block **918**). For example, the avionics unit **110** may receive a second input provided by a member of the flight crew via a user interface, such as via a controller **120**, or the second input may be automatically provided by one or more components of the integrated avionics system **100**. Based upon the second received input, a profile information display mode is selected for causing the air traffic display to be configured for displaying profile information for the one or more air traffic targets, including providing a second air traffic display comprised of a second software-generated depiction (Block **920**). For instance, the avionics unit **110** may then provide a second air traffic display comprised of a second software-generated depiction to one of the display device(s) (e.g., PFD **102**(**1**), PFD **102**(**2**), or MFD **104**) implemented on-board the first aircraft. The second air traffic display comprised of the second software-generated depiction **800**, such as shown in FIG. **8**, may provide detailed profile information for the air traffic targets **304**, including: a closest point of approach (CPA) range relative to aircraft **302**, an estimated time of arrival to the CPA, a callsign, a weight class category, a ground speed, track data, range, and bearing. The second air traffic display comprised of the second software-generated depiction (**800**) may be generated by the avionics unit **110** based upon the data which was dynamically received and aggregated by the avionics unit **110**.

CONCLUSION

Although the integrated avionics system **100** has been described with reference to example implementations illustrated in the attached drawing figures, it is noted that equivalents may be employed and substitutions made herein without departing from the scope of the invention as recited in the claims. Further, the integrated avionics system **100** and its components as illustrated and described herein are merely examples of a system and components that may be used to implement the present invention and may be replaced with other devices and components without departing from the scope of the present invention.

What is claimed is:

1. An integrated avionics system configured for implementation in an aircraft, the integrated avionics system comprising:
- a display device configured to furnish an air traffic display depicting air traffic surrounding the aircraft; and
- an avionics unit communicatively coupled with the display device, the avionics unit including:
  - a memory operable to store one or more modules; and
  - a processor coupled with the memory, the processor operable to execute the one or more modules to:
    - access traffic information corresponding to an air traffic target;
    - generate an air traffic target icon using the accessed traffic information, the target icon indicating the absolute heading of the air traffic target;
    - generate a relative motion vector using the accessed traffic information, the relative motion vector indicating the relative heading of the air traffic target with respect to the aircraft; and
    - control the display to present the target icon and relative motion vector so that the relative motion vector extends from the target icon.

2. The system of claim **1**, wherein the accessed traffic information is based upon dynamically received data from at least one of:
- an Automatic Dependent Surveillance-Broadcast (ADS-B) system; a Traffic Collision Avoidance System (TCAS); and a Traffic Information Services-Broadcast (TIS-B) system.

3. The system of claim **1**, wherein the processor is further configured to generate target icons and corresponding relative motion vectors for a plurality of air traffic targets.

4. The system of claim **1**, wherein the target icon presents a chevron shape with the apex of the chevron indicating the absolute heading of the target.

5. The system of claim **4**, wherein the relative motion vector is a line extending from the chevron.

6. The system of claim **1**, wherein the display indicates the location of the aircraft in relation to the target icon.

7. The system of claim **1**, further comprising an Automatic Dependent Surveillance-Broadcast (ADS-B) system.

8. An integrated avionics system configured for implementation in an aircraft, the integrated avionics system comprising:
- a display device configured to furnish an air traffic display depicting air traffic surrounding the aircraft; and
- an avionics unit communicatively coupled with the display device, the avionics unit including:
  - a memory operable to store one or more modules; and
  - a processor coupled with the memory, the processor operable to execute the one or more modules to:
    - access traffic information corresponding to an air traffic target;
    - generate an air traffic target icon using the accessed traffic information, the target icon comprising a chevron shape where the apex of the chevron indicates the absolute heading of the air traffic target;
    - generate a relative motion vector using the accessed traffic information, the relative motion vector indicating the relative heading of the air traffic target with respect to the aircraft; and
    - control the display to present the target icon and relative motion vector so that the relative motion vector extends from the chevron-shaped target icon.

9. The system of claim **8**, wherein the accessed traffic information is based upon dynamically received data from at least one of:
- an Automatic Dependent Surveillance-Broadcast (ADS-B) system; a Traffic Collision Avoidance System (TCAS); and a Traffic Information Services-Broadcast (TIS-B) system.

10. The system of claim **8**, wherein the display indicates the location of the aircraft in relation to the target icon.

11. A method for furnishing an air traffic display depicting air traffic within a monitored airspace surrounding an aircraft comprising:
- dynamically receiving and aggregating air traffic information describing the location of at least one air traffic target within the monitored airspace;
- generating an air traffic target icon using the traffic information, the target icon comprising a chevron shape where the apex of the chevron indicates the absolute heading of the air traffic target;
- generating a relative motion vector using the accessed traffic information, the relative motion vector indicating the relative heading of the air traffic target with respect to the aircraft; and
- controlling a display to present the target icon and relative motion vector so that the relative motion vector extends from the chevron-shaped target icon.

12. The method as recited in claim **11**, wherein the step of dynamically receiving and aggregating data comprises:
- dynamically receiving and aggregating data from: an Automatic Dependent Surveillance-Broadcast (ADS-B) system; a Traffic Collision Avoidance System (TCAS); and a Traffic Information Services-Broadcast (TIS-B) system.

13. The method as recited in claim **11**, further comprising controlling the display to indicate the location of the aircraft in relation to the target icon.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,437,112 B1
APPLICATION NO. : 14/737260
DATED : September 6, 2016
INVENTOR(S) : Philip A. Greene

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page
Item [63], Related U.S. Application Data is hereby added and reads:

--Related U.S. Application Data
Continuation of application No. 13/475,666, filed on May 18, 2012.--

Signed and Sealed this
Twenty-first Day of February, 2017

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office